

Technical Report 677

Cognitive Effort Requirements in Recall, Recognition, and Lexical Decision

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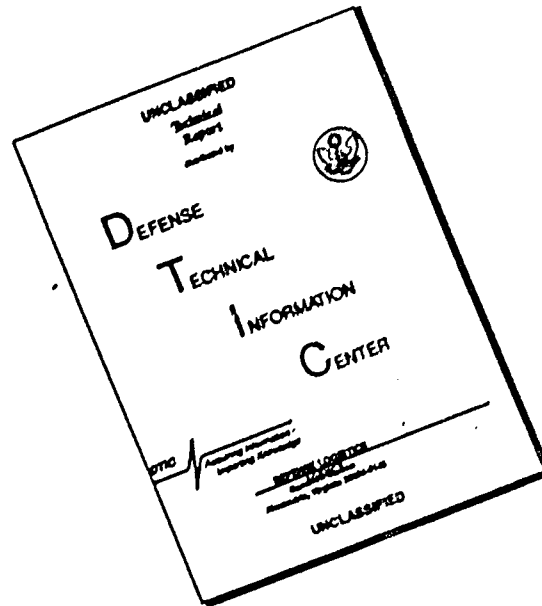
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Recall and recognition were tested to determine the relationship between cognitive effort requirements during study and later ability to remember studied items. Overall, the results of this research indicate that when individuals expect a recall test they use extensive or difficult processing operations which may involve elaborating the meaning of studied items. In contrast, when they expect a recognition test they use more superficial processing operations with less emphasis on meaning.

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FOREWORD

The research program of the Instructional Technology Systems Technical Area of the U.S. Army Research Institute for the Behavioral and Social Sciences includes a number of diverse projects which focus on military education and training. One facet of this program is an effort to improve acquisition and retention of the skills involved in military tasks. In order to effect this improvement, an understanding of the cognitive processes used in these tasks is required. This report describes a basic research project designed to explore the cognitive processes used during study by experienced learners when different tests of memory are expected, and when study materials are either familiar or unfamiliar. The results will be of interest to military trainers and educators and should also potentially be of use to students in the mastery of study materials.



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Technical Director

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COGNITIVE EFFORT REQUIREMENTS IN RECALL, RECOGNITION, AND LEXICAL DECISION

EXECUTIVE SUMMARY

Requirement:

To obtain information about the cognitive processes involved during study when different tests of memory are expected, and when study materials are either familiar or unfamiliar.

Procedure:

Cognitive effort requirements during study for free recall (e.g., essay type test), recognition (e.g., multiple choice type test), and an incidental learning task (e.g., word/nonword decisions) were assessed using a secondary reaction time task. Auditory probes were presented while individuals studied familiar or unfamiliar words and the time to respond to these probes was measured. Differences in latency scores provided information about the amount of cognitive effort expended during study for these memory tasks. Recall and recognition were tested to determine the relationship between cognitive effort requirements during study and later ability to remember studied items.

Findings:

Overall, the results of this research indicate that when individuals expect a recall test they use extensive or difficult processing operations which may involve elaborating the meaning of studied items. In contrast, when they expect a recognition test they use more superficial processing operations with less emphasis on meaning. Specific results were as follows:

1. Greater effort was devoted to study when a recall test was expected than when a recognition test was expected. This demonstrates that experienced learners (i.e., college students) engage in different study procedures when they expect different tests of memory, and that these procedures are more difficult for recall than for recognition.
2. When recognition was expected, unfamiliar words received greater effort than familiar words while these items were visible, and recognition performance was best for unfamiliar words. In contrast, when recall was expected, familiar words received as much effort as unfamiliar words, but were recalled more often. These findings suggest that successful recognition is related to the perceptual processing that occurs while an item is physically present. On the other hand, recall performance may be related to elaboration of item meaning. Specifically, since familiar items are meaningful, they are more amenable to semantic elaboration. Increased effort requirements for familiar items during study for recall may reflect greater elaboration for these items than for unfamiliar items.

3. When no test was expected, (lexical decision task) cognitive effort requirements were similar to those when recognition was expected, but were not similar to effort requirements when recall was expected. Moreover, although no test was expected, recognition test performance resembled performance when a recognition test was expected. In contrast, recall performance was poorer on the unexpected test than on the expected test. These findings further support the idea that individuals expecting a recognition test perform relatively superficial processing, whereas those expecting a recall test perform more difficult semantic elaboration.

Utilization of Findings:

This research indicates that experienced learners (i.e., college students) engage in different cognitive processes during study when they expect different tests of memory. These processes generally produce optimal performance on the expected test. Unlike these "expert" learners, many soldiers demonstrate a lack of effective study strategies. The present research suggests that one reason for this may be that these soldiers are unaware of the different requirements of various memory tests, and, consequently, do not engage in the type of cognitive processing that produces successful retrieval. These soldiers may benefit from training that increases their awareness of differences in memory demands for certain military tasks, and that, either directly or indirectly, induces the type of processing during study that is required to meet these demands.

COGNITIVE EFFORT REQUIREMENTS IN RECALL, RECOGNITION, AND LEXICAL DECISION

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COGNITIVE EFFORT REQUIREMENTS IN RECALL, RECOGNITION, AND LEXICAL DECISION

Recent developments in memory research have shown that retrieval in recall and recognition may be based on qualitatively different types of information stored during encoding. Recognition memory may rely on intraitem familiarity or interitem elaboration (Mandler, 1979; Jacoby & Dallas, 1981), whereas recall is primarily dependent on elaboration (Mandler, 1979, 1980). Familiarity is a product of perceptual integration of item features and is affected by increased exposure to the item (Mandler, 1980). Thus, multiple presentations of list items increase recognition performance despite instruction to forget (Bartz, 1976) or changed study to test context (Davis, Lockhart, & Thompson, 1972; Donaldson, 1981). Similarly, periods of maintenance rehearsal, whereby the subject rehearses but does not attempt to organize or elaborate list items, facilitate recognition (Woodward, Bjork, & Jongeward, 1973). Elaboration, on the other hand, involves the formation of relationships between list items or between a single list item and associated items in memory. Extensive elaborative processing may not always be required for recognition, especially when study and test conditions encourage a judgment based on familiarity or perceptual information. In contrast, recall is highly dependent upon this type of processing (Mandler, 1980).

One possible consequence of these different processing requirements is that individuals may optimize encoding of the information they expect to use during retrieval. Consistent with this notion, the expectation of a recognition test has been shown to produce high levels of performance for recognition, but not for recall. The expectation of a recall test, however, produces high levels of performance for both types of retrieval (Hall, Grossman, & Elwood, 1976; Balota & Neely, 1980). Thus, subjects expecting recognition may process the intraitem features necessary for later identification of each individual item, but may not engage in the interitem elaboration required for recall (Tversky, 1973). Subjects expecting recall may elaborate items, enhancing information useful in both recall and recognition.

In studies which manipulate retrieval expectancy, differences in encoding processes are inferred from systematic changes at retrieval. One purpose of the present research was to provide a measure of encoding differences independent of retrieval performance. This was accomplished by using a secondary task procedure in which a manual response to an auditory signal was performed concurrently with a primary task of studying for recall or recognition. Concurrent performance of primary and secondary tasks produces competition for the resources of a limited capacity central processor (Kahnemann, 1973; Kerr, 1973). Greater processing effort for the primary task leaves less processing capacity available and results in longer reaction times to the secondary signal. Eysenck and Eysenck (1979) have recently demonstrated that a primary task requiring elaborative semantic processing produces more effort than one requiring physical processing. Perceptual integration involves operations that resemble physical processing (Mandler, Goodman, & Wilkes-Gibbes, 1982). It was expected, therefore, that as a result of increased elaborative processing, encoding for a recall expectancy should require more effort than encoding for a recognition expectancy.

A second topic of interest in this research was the word frequency paradox (Gregg, 1976). High frequency (HF) words are recalled better than low frequency (LF) words, whereas LF words are recognized better than HF words (Bousfield & Cohen, 1955; Kinsbourne & George, 1974). In accounting for this paradox, Mandler (1979; 1980) has suggested that the amount of integrative processing required for an item is a function of its preexisting or baseline familiarity level. Low frequency words, with low baseline familiarity, require more extensive perceptual integration than HF words, and this extensive integration results in a larger increment in the familiarity information available for recognition. On the other hand, well-integrated HF words are meaningful units and are, therefore, more amenable than LF words to interitem elaboration. Greater elaborative processing results in higher recall for these items.

The reaction time data in the present experiment should provide some information about differential processing of HF and LF words. If word frequency effects in recognition are due to integration, and if subjects optimize their encoding strategy for the expected recognition test, then LF words should receive a greater expenditure of effort during encoding than HF words. Similarly, if word frequency effects in recall are due to elaborative processing, then HF words should receive more processing effort than LF words during encoding for a recall expectancy.

A third variable of interest was the time course of processing following the presentation of an item. In order to discover where the greatest processing differences might occur, cognitive effort requirements were measured at three positions. Auditory signals were presented at two positions during item presentation (100 msec and 300 msec after item onset) and at one position during the interitem interval (100 msec after item offset). Integration, as a perceptual process, should be closely linked to item presentation; differences in processing effort that are due to integrative processes should occur while the item is present. It is difficult, however, to predict the critical interval for elaboration. Elaborative processes may occur during item presentation as well as after removal of the item (i.e., during the interstimulus interval).

EXPERIMENT 1

Method

Design and Materials. Two retrieval expectancies (recall vs. recognition), two word frequencies (high vs. low), and three probe positions (100 msec vs. 300 msec vs. 600 msec) were crossed to produce a $2 \times 2 \times 3$ factorial design. All variables were within-subject factors. The experiment was run in two sessions. In one session subjects were tested under a recall expectancy, and in the other session they were tested under a recognition expectancy. Half of the subjects received recall during the first session; the remaining half received recognition. Within each session (each retrieval expectancy), half of the subjects were presented with a HF study list followed by a LF study list; the remaining subjects received a LF list followed by a HF list. The order of presentation for HF and LF lists remained constant across the retrieval expectancies for the individual subject.

Two separate pools of words were generated by selecting nouns of six to eight letters with either a very high or very low frequency of occurrence in

the Thorndike-Lorge (1944) word count. The selected HF and LF words were obtained from the categories of words occurring 100 or more times per 1,000,000 words (Thorndike-Lorge AA words) and at least once per 4,000,000 words, respectively. Four study lists of 35 words were constructed; two lists consisted of HF words, and two lists consisted of LF words. The first five words in each list served as practice trials. One HF and one LF word list were presented for study in recall, the remaining HF and LF lists were presented for study in recognition.

Words in the four study lists were presented for a duration of 500 milliseconds and there was a 6-second interval between items. Within each of the study lists there were six occurrences, at each of the three probe positions, of a 450 Hertz tone with a duration of approximately 75 milliseconds. Tones occurred 100, 300, and 600 milliseconds after word onset. The 600-millisecond tone also represented a position 100 milliseconds after word offset. To prevent probe anticipation, six of the remaining list words were presented without a tone, and six were associated with tones in random positions. The three measured probe positions, the randomly positioned tones, and the instances where no tones occurred were randomly assigned to the target words within each study list. The first five practice words were always associated with randomly positioned tones.

In addition to the study lists, there were two 60-item recognition lists (one HF and one LF). These lists were created by combining the 30 target words in the recognition study lists with 30 distractors selected from the same frequency word pool. Target and distractor items were randomly arranged in test booklets with the restriction that target items in the first and last two positions of a study list never occurred in the first or last two positions of a test list. Space was provided with each item for a recognition confidence rating on a 5-point scale ranging from "very confident" to "very unsure."

Finally, in order to establish a retrieval expectancy, two mixed frequency practice lists were constructed (one for each session). Each list consisted of six HF and six LF words chosen from the same word pools as the study and the test items. These lists were given prior to the study lists, and no tones were associated with the presentation of words in these lists. Twelve additional mixed frequency words served as distractors for the practice recognition test.

Procedure. Subjects were tested individually in two 1-hour sessions, 48 hours apart. Each session consisted of an initial practice test to establish a retrieval expectancy, presentation of a HF and a LF word list along with concurrent auditory probes, and retrieval of list items. A 5-minute distractor task intervened between presentation and test of each list, and there was a 5-minute interval between retrieval of the first study list and presentation of the second list.

All visual and auditory stimuli were presented by an Apple II Plus micro-computer. Visual stimuli appeared on a Sanyo video monitor with a 9-in. screen. Subjects were allowed to position this screen themselves for optimal viewing. Tones were generated by a speaker located inside the microcomputer. This speaker was positioned 1-1/2 feet to the left of the subject. Manual responses to the tones were made by pushing a button on a small box. Subjects were allowed to position this box for maximum ease of responding.

On each trial, an asterisk preceded the presentation of a word. The asterisk appeared in the same position as the word and was replaced with a blank screen after 500 milliseconds. The asterisk signaled the occurrence of a new word and warned the subject to focus attention on the screen. Five hundred milliseconds after asterisk offset, a word appeared on the screen and remained in sight for another 500 milliseconds. A 5-second period, in which the screen was again blank, intervened between word offset and the asterisk signalling the next word.

For the practice test, subjects were instructed to expect either a recall or a recognition test depending upon the assigned retrieval expectancy for that session. In the recall session, subjects were told that they would be required to recall the words presented on the screen. In the recognition session, they were told that they would be required to discriminate between items they had seen in the list and items they had not seen. To emphasize the importance of studying for the expected retrieval test, tones were not presented during study of the practice list. Following the presentation of the practice list, subjects circled various digits in a random number table of three-digit numbers for 5 minutes and were then given 5 minutes to retrieve the practice items.

For the remainder of the session, the subjects performed two concurrent tasks during study list presentation. As their primary task, they were instructed to study the words appearing on the screen for the relevant retrieval test. As their secondary task, they were instructed to listen for the occurrence of auditory stimuli while studying. Upon hearing a tone, they were to respond by pressing a single reaction time button with the index finger of their dominant hand. It was emphasized, however, that studying to increase retrieval performance was the more important of the two tasks. As mentioned before, the first five words were designated as practice trials. These words were presented to allow the subjects to become acquainted with the procedure and were not included in any later analyses. After list presentation and the distractor interval, subjects were given a self-paced retrieval test corresponding to the expectancy created by the instructions and practice test.

Subjects. Thirty-six students enrolled in an intermediate level psychology course at George Washington University participated in the experiment. Subjects were randomly assigned to a retrieval expectancy and frequency presentation order. They were paid \$8.00 for their participation.

Results and Discussion

The results of the retrieval tests are presented in Table 1. Recall proportions and recognition hit rates were used for the main analysis. Unless otherwise indicated all effects reported as significant reached a level of at least $p < .05$. To determine whether there was an effect of order of presentation for word frequency and retrieval test, the data were first submitted to a 4 (order) \times 2 (retrieval expectancy) \times 2 (word frequency) ANOVA. This analysis produced no main effect of order nor any interactions with this factor. The data were, therefore, collapsed across order and reanalyzed. The subsequent 2 (retrieval expectancy) \times 2 (word frequency) ANOVA revealed a significant main effect of retrieval type, $F(1,35) = 396.77$, $MSe = .020$, but no effect of frequency, $F(1,35) = 2.44$, $MSe = .013$. The interaction between

retrieval type and word frequency was significant, $F(1,35) = 67.06$, $MSe = .006$, thereby indicating that the typical word frequency paradox had been replicated. An analysis of simple effects within this interaction showed that, as expected, HF words were recalled better than LF words, $F(1,61) = 34.71$, $MSe = .009$, whereas LF words were recognized better than HF words, $F(1,61) = 10.71$.

Table 1

Retrieval Data for Experiments 1 and 2

	High frequency word Mean SD	Low frequency word Mean SD	Nonword Mean SD
<u>Experiment 1</u>			
Recall	.34 (.14)	.21 (.13)	--
Recognition			
Hits	.71 (.15)	.78 (.12)	--
False alarms	.22 (.15)	.15 (.13)	--
Corrected recognition	.63 (.18)	.73 (.16)	--
d'	1.52 (.73)	2.00 (.90)	--
<u>Experiment 2</u>			
Recall	.10 (.06)	.07 (.08)	.02 (.02)
Recognition			
Hits	.69 (.19)	.78 (.13)	.70 (.11)
False alarms	.29 (.19)	.29 (.14)	.29 (.13)

The effect of word frequency in the recognition data was further demonstrated by greatly reduced false alarm rates for LF words in comparison to HF words, $F(1,35) = 10.50$, $MSe = .008$, and by higher corrected recognition [$\% \text{ correct} = (\% \text{ hits} - \% \text{ false alarms}) / (100\% - \% \text{ false alarms})$], $F(1,35) = 10.38$, $MSe = .015$, and higher d' scores, $F(1,35) = 11.71$, $MSe = .354$. These results compare favorably with the results of other word frequency experiments in which no secondary task was performed (cf. Balota & Neely, 1980).

Since subjects were apparently studying in response to the relevant retrieval expectancy, their reaction time scores should provide some information about the encoding requirements of the expectancy. Mean reaction time scores for high and low frequency words during a recall and a recognition expectancy are presented in Table 2. A preliminary 4 (order) x 2 (retrieval expectancy) x 2 (word frequency) x 3 (probe position) ANOVA for this data produced neither a main effect of order nor any interactions with this factor. The data were, therefore, collapsed across order and reanalyzed. These data are presented

in Figure 1. A 2 (retrieval expectancy) x 2 (word frequency) x 3 (probe position) ANOVA produced a large effect of retrieval expectancy. Overall reaction time was greater by 64.33 milliseconds when recall rather than recognition was expected, $F(1,35) = 12.73$, $MSe = 35120.23$. It appears that processing for recall requires more cognitive effort than processing for recognition. In agreement with the retrieval data, there was no main effect of word frequency, $F(1,35) = 2.33$, $MSe = 24142.33$, but frequency did not interact with expectancy in either the two-way, $F(1,35) < 1$, $MSe = 20761.23$, or the three-way (with probe position), $F(2,70) = 1.34$, $MSe = 6976.24$, interaction. The absence of a significant interaction is somewhat surprising and will be discussed in more detail later.

Table 2

Reaction Time Data for Recall, Recognition, and Lexical Decision

Condition	Frequency	Probe position					
		P1		P2		P3	
		Mean	SD	Mean	SD	Mean	SD
Recall	High	474.68 (248.32)		413.92 (191.61)		428.13 (201.01)	
	Low	490.23 (184.60)		423.25 (151.79)		430.30 (155.39)	
Recognition	High	388.81 (129.55)		343.87 (117.73)		349.66 (137.00)	
	Low	409.90 (180.37)		417.84 (157.67)		364.47 (141.60)	
Lexical	High	671.65 (249.36)		591.35 (222.12)		555.31 (240.01)	
	Low	742.35 (360.09)		660.29 (277.05)		574.60 (250.76)	
	Nonword	716.77 (302.04)		643.00 (265.94)		581.44 (235.19)	

There was a main effect of probe position, $F(2,70) = 14.07$, $MSe = 6859.67$, as well as an expectancy by position interaction, $F(2,70) = 5.10$, $MSe = 3961.28$, showing that across the processing interval the pattern of effort demand differed for recall and recognition. An analysis of simple effects within this interaction indicated that recall received greater processing effort than recognition at probe positions 100 milliseconds, $F(1,51) = 17.32$, $MSe = 14347.60$, and 600 milliseconds, $F(1,51) = 13.06$, after item onset. The difference in effort at 300 milliseconds was not significant, $F(1,51) = 3.57$. It appears that elaborative processing, as reflected in higher effort for recall than for recognition, occurs during item presentation as well as after item offset. An examination of Figure 1 suggests that the absence of a difference in recall and recognition processing effort at 300 milliseconds is probably a function of continued effort at this position for LF words under

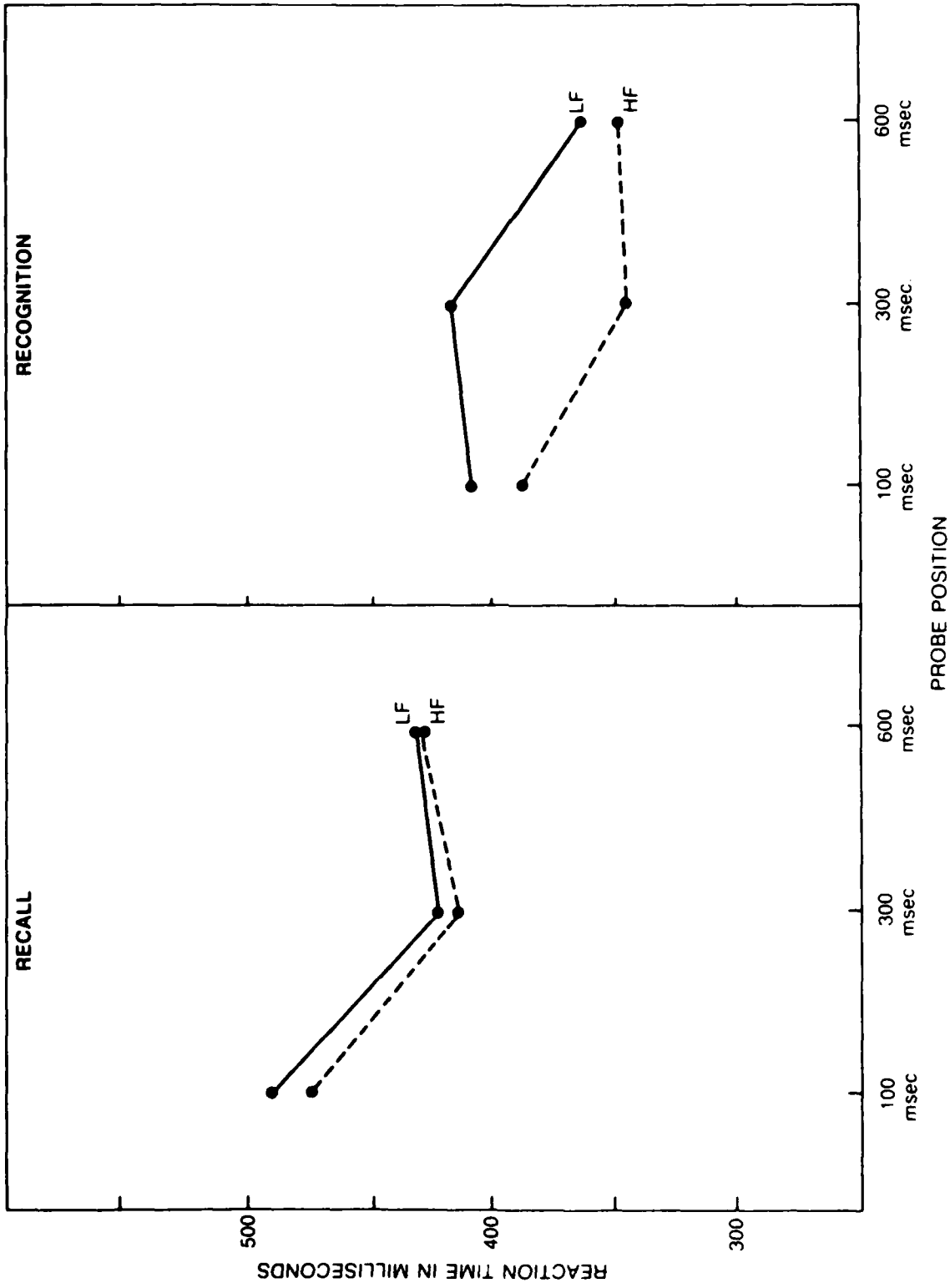


Figure 1. Mean probe reaction times as a function of word frequency and probe position for a recall and a recognition test expectancy.

the recognition expectancy compared with a decrease in effort for these words under a recall expectancy. The frequency by position interaction, however, failed to reach significance, $F(2,70) = 1.65$, $MSe = 6343.34$. This is perhaps due to the absence of frequency effects at all three probe positions for a recall expectancy.

In order to further examine the effect of retrieval expectancy, separate analyses were conducted for recall and recognition. A 2 (word frequency) \times 3 (probe position) ANOVA for the recognition reaction time data produced a significant effect of word frequency, $F(1,35) = 5.13$, $MSe = 14108.36$, showing that LF words require greater processing effort than HF words. There was also a main effect of probe position, $F(2,70) = 7.53$, $MSe = 4296.29$, indicating that capacity requirements changed across the processing interval. Of greater interest, however, was a significant word frequency by probe position interaction, $F(2,70) = 6.38$, $MSe = 2982.21$. An analysis of simple effects showed that the major difference between these words appeared at the second probe position, 300 milliseconds after word onset, $F(1,65) = 14.72$, $MSe = 6690.93$. This finding shows that the type of processing for HF and LF words differs under a recognition expectancy. Greater processing effort for LF words than for HF words at 300 milliseconds may reflect differences in perceptual integration for these items. Post hoc comparisons (Neuman-Keuls) of probe position means within each frequency type support this interpretation. Processing effort for HF words decreased between 100 milliseconds and 300 milliseconds, while effort for LF words showed no change in the same interval. Effort did decrease for LF words, but only after word offset (600 msec). It appears that LF words undergo continuous analysis while in sight, whereas HF words do not. The more extensive perceptual processing for LF words during this interval may have enhanced later recognition of these words. The failure of HF words to receive additional processing at this time may have contributed to their subsequent poor recognition.

Compared to the recognition results, the results of the analysis of reaction time data obtained under a recall expectancy produced a completely different picture. Contrary to our expectations, HF words did not receive greater effort than LF words during recall encoding. In fact, LF words resulted in slightly longer reaction times than HF words, although neither the effect of frequency, $F(1,35) < 1$, $MSe = 30795.21$, nor the interaction of frequency and probe position, $F(2,70) < 1$, $MSe = 10337.36$, was significant. The only effect to reach significance was that of probe position, $F(2,70) = 12.92$, $MSe = 6524.67$. A post hoc analysis (Neuman-Keuls) of probe position means collapsed across word frequency indicated that processing effort decreased between 100 and 300 milliseconds, but not between 300 and 600 milliseconds.

The absence of a frequency by probe position interaction in recall, along with its presence in recognition, and the differential time course of processing under the two expectancies suggest one possible explanation for the failure to obtain an overall frequency by expectancy interaction in the reaction time data. During item presentation (100 msec and 300 msec positions), LF words receive more processing than HF words under both retrieval expectancies, although this difference only reached significance during recognition. More extensive elaborative processing for HF words under recall instructions could be occurring, but the effort associated with this processing may not be sufficient to exceed the effort expended for perceptual processing of LF words. A clear effect of elaborative processing for HF words may appear only when

perceptual processing is completed (after item offset). It is possible that at some point past our last systematically measured probe position, effort requirements for HF and LF words under the recall expectancy may parallel the retrieval data.

In short, the results of Experiment 1 suggest that the type of processing for recognition is quite different from that for recall. Under a recognition expectancy, greater demands for processing effort prior to item offset are associated with successful retrieval performance. Low frequency words require more effort and are recognized better than HF words. Thus, recognition encoding processes seem to be closely related to item-induced perceptual processes (see also Jacoby & Dallas, 1981). Under a recall expectancy, however, item-induced processing effort does not account for later retrieval. Processing effort for HF and LF words does not differ, but HF words are recalled better than LF words. Greater overall processing effort for a recall expectancy than for a recognition expectancy suggests that the former induces some type of elaborative processing. This processing appears to be superimposed over the simpler operations involved in word identification. Furthermore, although the effort required by elaborative processing is not sufficient to reverse the differences in effort associated with processing of HF and LF words, it is sufficient to eliminate these differences. Word frequency effects in recall may be dependent upon this expectancy-induced elaboration.

In order to further examine the issue of expectancy-induced versus item-induced processing, a second experiment was conducted. In this experiment, a lexical decision task, in which the subjects decided whether an item was a word or a nonword letter string, served as the primary task. This incidental learning procedure should reveal differences in reaction time for recall and recognition processing that stem primarily from word frequency and not from retrieval expectancy. In addition, comparison of the retrieval data from both experiments may clarify the contribution of retrieval expectancy to the word frequency paradox.

EXPERIMENT 2

The procedure of Experiment 1 was modified in order to examine processing effort and retrieval performance for HF and LF words in the absence of a retrieval expectancy. Instead of studying for an expected recall or recognition test, subjects performed a lexical decision task in which they were asked to decide whether an item was a word or a nonword. Mandler et al. (1982) have proposed that lexical decisions are based primarily on item familiarity and may involve only minimal access to meaning. In agreement with this idea, a lexical decision response, like simple word identification (Jacoby & Dallas, 1981), is influenced by increased perceptual fluency of items, but not by prior encoding context or relationships along items (Carroll & Kirsner, 1982). Thus, a lexical decision involves operations that are related to intraitem integration, but not to interitem elaboration (Mandler et al., 1982).

The amount of effort required for intraitem integration depends upon the baseline familiarity of an item (Mandler, 1980). Moreover, greater effort during integration leads to a larger increment in familiarity. Since a familiarity-based recognition judgment relies on an evaluation of the ratio of incremented familiarity to the sum of baseline familiarity plus the

increment (Mandler, 1979; 1980), a higher increment in familiarity should result in larger familiarity ratios and better recognition performance. Therefore, in comparison to familiar items, unfamiliar items should require more effort which, in turn, should produce more familiarity information and better recognition. Two studies provide some support for this idea. First, Becker (1976) has shown that secondary task reaction time responses obtained during a lexical decision are primarily dependent on the preexperimental familiarity of stimulus items. Specifically, unfamiliar LF words produce longer reaction times than familiar HF words. Second, recognition performance following a lexical decision task is higher for LF than for HF words (Mandler et al., 1980).

The reaction time and retrieval results in the present experiment are expected to parallel those of the two aforementioned studies. More important, however, if a recognition expectancy and a lexical decision task induce primarily integrative processing, then effort requirements for HF and LF words in this experiment should resemble the effort requirements observed for HF and LF words during the recognition expectancy in Experiment 1. In addition, to the extent that later recognition test performance is dependent on incremented item familiarity, a lexical decision should yield recognition results similar to those following the recognition expectancy. In contrast, the absence of elaborative processes in lexical decision (Mandler et al., 1982) should result in different effort requirements for this task and a recall expectancy. A smaller word frequency effect may also occur in recall test performance due to the failure to elaborate high frequency words.

Method

Design and Materials. The design of the experiment was a 2 x 2 x 3 factorial with word frequency (high vs. low), lexical type (word vs. nonword), and probe position (100 msec vs. 300 msec vs. 600 msec) as within-subject variables. All subjects first performed a lexical decision task for a HF and a LF list. The order of presentation of word frequency was counterbalanced; half of the subjects received a HF list followed by a LF list and the remaining half received the reverse order. After presentation of the second list, all subjects received an unexpected recall test for both HF and LF lists. Following recall, an unexpected recognition test was given for these items.

The HF and LF study lists for the lexical decision task were created from the four study lists used in Experiment 1. Following a procedure described by Becker (1976), nonword items were produced by altering one vowel in each word. This procedure ensured that these items were visually and phonetically similar to actual words. The inclusion of nonword homophones that could be mistaken for a word with the same pronunciation was avoided. Words were transformed in this way for one of the original HF and LF lists. The HF nonword items were randomly combined with the remaining list of HF words to produce a 60-item HF study list. The LF words and nonword items were combined in a similar fashion to produce a LF study list.

For each lexical type within the HF and the LF study lists there were six occurrences of a 450 Hertz tone at each of the three measured probe positions. Twelve of the remaining items were associated with tones in random locations and 12 were presented without a tone. Probe locations were randomly assigned to items of each lexical type in both lists.

The recognition test list contained 120 target items and 120 distractors. The distractors consisted of the original distractor words for the HF and LF lists in Experiment 1 and 60 additional nonword distractors constructed in the same fashion as the target nonwords.

Procedure. As in Experiment 1, subjects performed two tasks concurrently. Unlike the previous experiment, however, an incidental learning situation was established by telling subjects that the purpose of the experiment was to study the way people classify visually presented items as words or nonwords. For their primary task, subjects were told that several items would appear individually on the video screen, preceded by an asterisk. Their task would be to determine whether each item was a word or a nonword. In order to approximate the encoding conditions in Experiment 1 and also to avoid the possibility of response competition, no overt lexical decision response was required until after the presentation and response to an auditory probe. The subjects were instructed that soon after a word disappeared from the screen, a plus sign (+) would appear. Upon its appearance they were to push one of two buttons, using the middle and index finger of their nondominant hand, to indicate a YES (word) or a NO (nonword) response. The two buttons were clearly marked with a Y and a N.

Subjects performed a secondary task identical to the one in the first experiment, and visual stimuli were presented with the same timing characteristics. However, the following changes were made in the interitem interval to allow for the placement of the lexical decision signal. Three seconds after item offset, the signal calling for the overt lexical decision response appeared and remained on the screen for 500 milliseconds, and the interitem interval was increased to 7 seconds.

To familiarize the subjects with the procedure, they were first given a 30-item practice list consisting of 15 items of each lexical type. After the practice list, they received either a HF or a LF study list which was followed by presentation of the second study list of the opposite frequency. Immediately after the presentation of the second list, subjects were given an unexpected recall test for items in both lists. They were explicitly instructed to recall both words and nonword items. Upon completion of the recall test, subjects were given an unexpected YES-NO recognition test for the HF, LF, and nonword items. They were also instructed to rate their confidence in each recognition judgment. The recall and recognition tests were self-paced.

Subjects. Eighteen students from an intermediate level psychology course at George Washington University served as subjects. Individuals who participated in Experiment 1 were excluded from this group. All subjects were paid \$6.00 for their participation.

Results and Discussion

The retrieval data for HF words, LF words, and nonword items are presented in Table 1. Unless otherwise indicated all effects reported as significant reached a level of at least $p < .05$. Preliminary analyses indicated that recall proportions, $F(1,17) < 1$, $MSe = .001$, hit rates, $F(1,17) < 1$, $MSe = .007$, and false alarm rates, $F(1,17) = 1.23$, $MSe = .007$, for the HF and LF nonwords did not differ. Therefore, scores for the nonword items on each of these

measures were collapsed to form one category of nonwords. Since the main purpose of this experiment was to compare HF and LF words in the absence of a retrieval expectancy, the data for these two types of items will be discussed first. A 2 (retrieval type) x 2 (word frequency) ANOVA performed on recall proportions and recognition hit rates produced a main effect of retrieval type, $F(1,17) = 1009.60$, $MSe = .008$. There was no main effect of frequency, $F(1,17) < 1$, $MSe = .022$, but frequency did interact with retrieval type, $F(1,17) = 5.67$, $MSe = .011$. An analysis of simple effects within this interaction indicated that, in agreement with Experiment 1, LF words were recognized better than HF words, $F(1,30) = 4.44$, $MSe = .016$. However, HF words were not recalled better than LF words, $F(1,30) < 1$. It appears that recognition hits following a lexical decision task are similar to those following a recognition expectancy, whereas recall after lexical decision differs from recall following a recall expectancy.¹ It is possible that the absence of the usual word frequency effect is due to the overall poor level of recall in this experiment. However, similar results in both overall retrieval rates and magnitude of frequency differences have been obtained by Mandler et al. (1982). Together, these results provide converging evidence that a retrieval expectancy plays a smaller role in recognition word frequency differences than it does in recall word frequency differences.

False alarm rates in this experiment did not differ for HF and LF words, $F(1,17) < 1$, $MSe = .009$. This result is at odds with the usual finding of lower false alarm rates for LF words (Glanzer & Bowles, 1976; Exp. 1, this paper). There are two possible explanations for this result. First, Mandler et al. (1982) have suggested that minimal processing of items during study may raise FA rates by reducing target distinctiveness at retrieval. Thus, in the present experiment, LF words may have failed to receive the degree of processing needed to make them sufficiently distinctive from their distractors. A second explanation is that the false alarm rate for LF words could have been affected by the resemblance between these items and nonwords. Previous research has shown that increasing the ratio of distractors to targets produces corresponding increases in false alarm rates (Postman, 1950; Davis, Sutherland, & Judd, 1961; Teghtsoonian & Teghtsoonian, 1970). Since nonword items resemble LF words, they may have served to increase the overall set of LF distractors, thereby increasing false alarm rates. Although both of these explanations are plausible at this point, the reaction time data, which will be discussed later, provide some support for a distinctiveness explanation.

The retrieval results for nonwords are presented in Table 1. A comparison with some recent results reported by Mandler et al. (1982) is the only interesting aspect of the results for nonword items. These authors have shown a monotonic linear effect of word frequency (nonwords < LF words < HF words) on recall, but a paradoxical curvilinear effect for hit rates (nonwords < LF

¹Because of the incidental instructions, recall in the present experiment followed presentation of the second list, whereas in Experiment 1, recall was given after each list. Although this manipulation might have affected the overall magnitude of recall in this experiment, there is no apparent reason why it should alter the word frequency effect. Therefore, differences in word frequency in the two experiments can be attributed to initial encoding processes. Likewise, note that recognition in this experiment followed recall and was tested for both lists.

words > HF words). A 2 (retrieval expectancy) x 3 (lexical type) ANOVA on recall proportions and hit rates in the present experiment showed a similar trend. There was a main effect of retrieval type, $F(1,17) = 1283.17$, $MSe = .009$, a marginal effect of lexical type, $F(2,34) = 2.65$, $MSe = .014$, $p < .08$, and a retrieval type by lexical type interaction, $F(2,34) = 4.41$, $MSe = .007$. Further analyses (Neuman-Keuls) showed that, in agreement with Mandler et al. (1982), LF words resulted in significantly higher hit rates than HF words or nonwords, and the latter two categories did not differ from each other. Likewise, HF words were recalled somewhat better than LF words, and LF words were recalled somewhat better than nonwords, although these differences were not significant. HF words, however, were recalled better than nonwords.

The reaction time data for this experiment provide some information about processing requirements for high and low frequency words in the absence of a retrieval expectancy. Mean reaction time scores for these items as well as for nonwords are presented in Table 2. These data are graphically represented in Figure 2. A preliminary analysis indicated that the reaction times for nonword items created from HF and LF words did not differ, $F(1,17) = 1.13$, $MSe = 19889.93$. Therefore, to simplify interpretation, data for these items were collapsed to form a single nonword category. A 3 (lexical type) x 3 (probe position) ANOVA for these data revealed a main effect of lexical type, $F(2,34) = 3.96$, $MSe = 10939.63$, demonstrating differences in processing effort for the three types of items. The effect of probe position was also significant, $F(2,34) = 16.19$, $MSe = 16715.94$, but the interaction of probe position by lexical type was not significant, $F(4,68) < 1$, $MSe = 8232.39$. Thus, effort requirements decreased progressively across the processing interval, but this decrease occurred in a similar fashion for HF, LF, and nonword items.

Neuman-Keuls analyses performed on lexical type means collapsed across probe position showed that reaction times did not differ for LF words and nonwords. Both of these items, however, produced longer reaction time scores than HF words. The greater effort requirements for LF words compared to HF words are consistent with recognition results in Experiment 1 and support Mandler's (1980) suggestion that effort requirements at presentation depend on the baseline familiarity value of items. Low frequency words have lower baseline familiarity levels than HF words. The greater processing effort required for perceptual integration of these words, in comparison to the HF words, results in a greater increment in familiarity and leads to higher hit rates.

The interpretation of effort requirements for nonwords is more complex. According to Mandler et al. (1982), nonwords have no baseline familiarity. Hence, the increment in familiarity resulting from a previous presentation cannot be evaluated for these words. Recognition judgments in this case must be based on "sheer" familiarity. Thus, in the present experiment, although nonwords received as much processing effort as LF words, they did not produce similar levels of recognition performance because the ratio of incremented to baseline familiarity could not be evaluated. This interpretation was used by Mandler et al. (1982) to account for the paradoxical curvilinear hit rate function for HF words, LF words, and nonword items in their recognition data and can also apply to the reaction time and retrieval results in the present experiment. Regardless of the interpretation, the similarity in effort for LF words and nonwords suggests that during the stimulus presentation interval processing for these items is primarily perceptual.

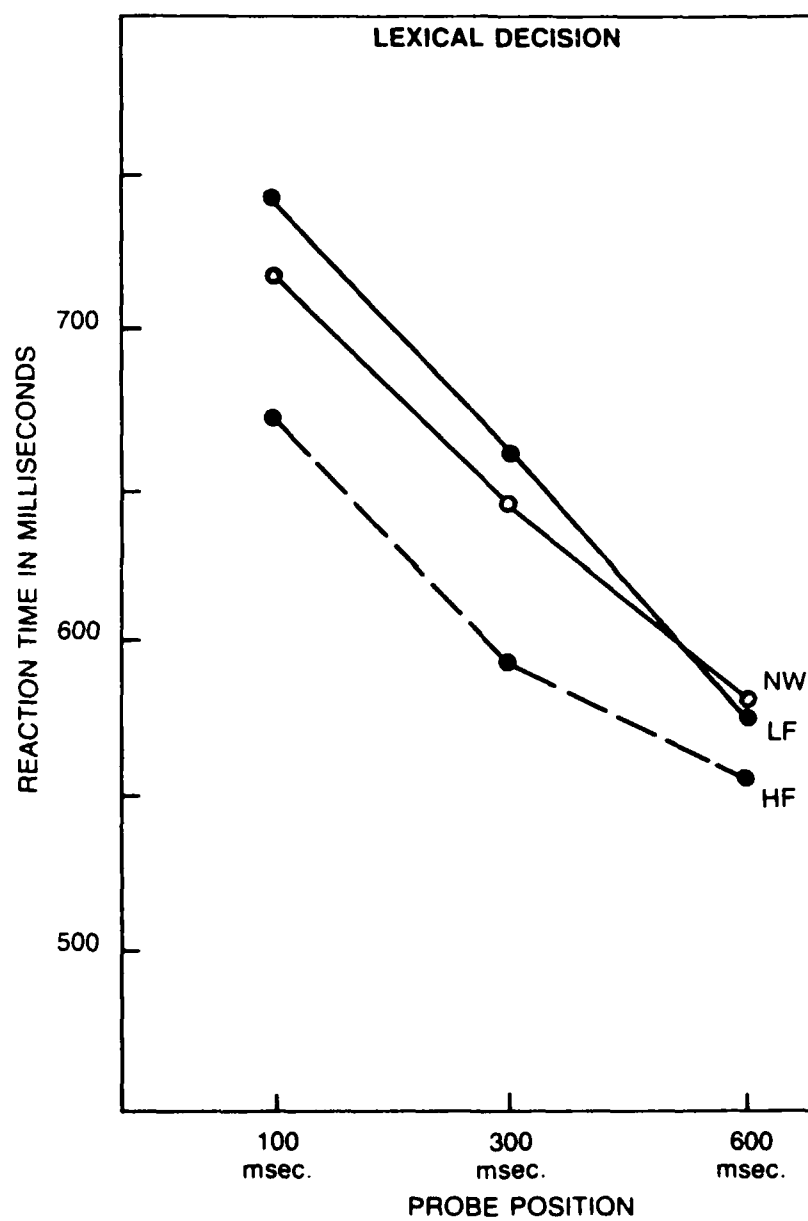


Figure 2. Mean probe reaction times as a function of lexical type (HF word, LF word, nonword) and probe position for a lexical decision task.

Although the effort requirements for LF and HF words under a recognition expectancy are similar to those for a lexical decision task, data on the time course of processing suggests certain differences between these two tasks. A Neuman-Keuls analysis of probe position means collapsed across lexical type indicated that cognitive effort progressively decreased as the time from item onset increased. Reaction time was greater at position 1 than position 2 and at position 2 than at position 3. Evidently, during a lexical decision task processing of items is quite brief. During recognition, however, there was continued allocation of effort to LF words while they were in sight, and reaction time decreased only after word offset. Thus, studying under a recognition expectancy appears to induce processing beyond that of lexical decision. It should be noted that the additional processing in recognition occurs primarily with LF words. The absence of this processing in the lexical decision task may, therefore, account for the unusually high FA rates for LF words in this experiment.

Finally, the pattern of processing effort in the lexical decision task was quite different from that obtained under a recall expectancy. In addition to the absence of a word frequency effect in reaction time data for the recall expectancy, the most important difference was in the time course data. The allocation of effort in recall remains high during item presentation and does not decrease after word offset. The brief processing during the lexical decision task, along with the poor subsequent recall provides further evidence that elaborative processing does not occur in a lexical decision task (see also Mandler et al., 1982). Moreover, the attenuated word frequency effect observed in this test may be due to the absence of elaborative processing for the meaningful HF words.

GENERAL DISCUSSION

The results of these experiments show that encoding operations reflected by patterns of processing effort during study vary in response to the type of retrieval test expected. A recall expectancy required considerably more processing effort than a recognition expectancy and effort requirements across the presentation interval for HF and LF words were different for the two expectancies. Effort requirements for an incidental lexical decision task revealed word frequency effects similar to those observed for a recognition expectancy. In addition, recognition performance following a recognition expectancy and a lexical decision task was related to effort requirements for high and low frequency words prior to their offset. Recall performance, however, was not related to processing effort during a recall expectancy and a lexical decision task. Several aspects of these results lead us to suggest that processing under a recognition expectancy is somewhat similar to processing during a lexical decision task. In both cases, this processing seems to be based primarily on perceptual processing of individual items. Processing under a recall expectancy, however, seems to be quite different and may involve interitem elaboration.

Before considering the evidence for different types of processing, two limitations of the secondary task technique and cognitive effort measure should be mentioned. First, by assessing effort at study, we have emphasized only processing differences in encoding. Clearly, retention is a joint function of encoding activities and retrieval conditions (Tulving & Thompson,

1973). A complete account of recall and recognition differences should consider effort demands at encoding as well as at retrieval. Second, and more important, several investigators have suggested that a quantitative measure of performance such as effort does not shed any light on the nature of underlying mental operations involved in retention (Jacoby, Craik, & Begg, 1979). Although this assumption is correct in certain situations, the present experiment shows that by varying the nature of stimulus materials and by examining the time course of processing, the reaction time to secondary auditory signals may yield some information about qualitative differences in processing. In agreement with other findings (Eysenck & Eysenck, 1979), our data reveal a complex relationship between expended processing capacity and retention. This complexity clearly makes interpretation more difficult. Nevertheless, we suggest that the complexity is probably due to the differential time course of the various mental operations requiring effort and that the use of a secondary task has yielded some useful information about qualitative differences in processing for recall and recognition.

When the type of test is known, individuals apparently alter the nature of their processing operations, perhaps to enhance information that will be useful for the expected retrieval test (Tversky, 1973; Hall, Grossman, & Elwood, 1976; Balota & Neely, 1980). Recognition benefits from intraitem organization or perceptual integration; recall benefits from interitem organization or elaboration (Mandler, 1979; 1980). Thus, one explanation for the differences observed in processing effort for a recognition and a recall expectancy may be that a recognition expectancy induces processing of primarily a perceptual nature, whereas a recall expectancy induces elaborative processing. The involvement of perceptual integration in recognition is indicated by the different effort demands for HF and LF words. Low frequency words, which require more extensive or more difficult perceptual integration (Mandler, 1980), produce longer reaction times prior to offset than well-integrated HF words. Moreover, the additional perceptual processing of LF words is associated with better recognition of these words. Recognition test performance, therefore, seems to be related to item-induced perceptual processing.

The role of perceptual processing under a recognition expectancy becomes clearer when effort requirements and test performance for recognition are compared with those for lexical decision. In agreement with the results for a recognition expectancy, LF words required more cognitive effort than HF words in lexical decision and were subsequently recognized better than HF words. A lexical decision task involves only minimal access to meaning and is unlikely to involve elaborative processing (Mandler et al., 1982). Thus, word frequency differences in reaction times and in subsequent recognition performance in this task are not a result of elaborative processing. Instead, they might be due to the perceptual processes that occur during item presentation. Greater effort devoted to perceptual processing during item presentation results in better recognition, even in the absence of a retrieval expectancy. The similarity in effort demands for LF and HF words in this task and under a recognition expectancy provides further support that subjects expecting recognition may also engage in primarily perceptual processing.

Although processing demands during a recognition expectancy are similar to those during lexical decision, certain differences in the time course of processing suggest that these two tasks are not identical. In recognition, effort for LF words does not decrease while these words are in sight. In

contrast, for lexical decision effort for both LF and HF words consistently decreases over the presentation interval. These two patterns of processing effort may represent differences in attention to item information made available during perceptual integration. During lexical decision, only that information required to determine lexical status receives attention. The expectancy of a recognition test, however, induces greater attention to item information. One result of the increased attention may be the formation of a more distinctive memory trace (Lockhart, Craik, & Jacoby, 1976). In the present study, increased effort, and possibly increased distinctiveness, does not influence hit rates, which are almost identical during a recognition expectancy and lexical decision. As discussed earlier, however, the additional effort during a recognition expectancy may increase target/distractor discriminability and may be responsible for the lower false alarm rates for LF words.

Unlike recognition and lexical decision, cognitive effort requirements for a recall expectancy failed to show a word frequency effect and, therefore, did not seem to be related to subsequent recall performance. HF words did not require more effort than LF words but they were recalled better. One reasonable explanation for this finding is that a recall expectancy induces elaborative processing which operates most effectively with semantic information. Thus, meaningful HF words receive a greater relative increase in cognitive effort than LF words, and this serves to mask word frequency differences in the reaction time data that are due to perceptual characteristics of the study items. The additional elaborative processing may also increase recall for HF words, thereby enhancing word frequency effects at retrieval.

Although this account is speculative, two findings in the present research support the suggestion that a recall expectancy involves elaborative processing. First, a recall expectancy requires considerably more processing effort than a recognition expectancy. Since other experiments have shown that semantic elaboration requires more effort than physical processing (Eysenck & Eysenck, 1979), it seems reasonable to assume that the greater effort in recall reflects elaborative processing. The fact that the additional processing occurs after item offset as well as during item presentation also suggests that processing under a recall expectancy is not linked to perceptual processing of items. Second, a lexical decision task, which does not require elaborative processing, leads to an overall poor level of recall. Furthermore, the usual word frequency effect for recall is not obtained after a lexical decision task. It appears, therefore, that better recall of HF words under a recall expectancy might be due to additional elaborative processing induced by this task. Higher recall for HF words than for LF words may not occur when a task requires minimal access to meaning.

In summary, the present analysis of cognitive effort requirements during encoding shows that a lexical decision task and a recognition expectancy induce encoding operations that are different from those induced by a recall expectancy. Processing for lexical decision involves primarily perceptual integration. Processing for recognition is similar and may involve operations that serve to enhance information resulting from perceptual integration. Unlike these two, processing for recall involves primarily interitem elaboration. These encoding processes for recognition and recall appear to be optimally suited to their respective retrieval tests.

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